DEVICE FOR DETERMINING AND INDICATING MASS NUMBERS IN A MASS SPECTROMETER

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ABSTRACT

Device in a mass spectrometer for determining and indicating mass numbers, in which the electromagnet, the purpose of which is to deflect the ion current of the mass spectrometer consist of two articulated connected members, and in which a force measuring means, preferably a load cell, is connected between said members and is giving an output signal related to the ion current deflecting magnetic field. Alternatively a second electromagnet is designed as described, said second magnet being electrically connected to said first electromagnet, in the air gap of which the ion current is passed and is being deflected.

6 Claims, 5 Drawing Figures
DEVICE FOR DETERMINING AND INDICATING MASS NUMBERS IN A MASS SPECTROMETER

The present invention relates to a device for determining and indicating mass numbers in a mass spectrometer.

Mass spectrometers have for a long time been used in the analysis of organic compounds, for determination of the enrichment of stable isotopes and for determination of exact molecular masses etc. The methods, applied for determination of mass numbers in a mass spectrometer, however have been relatively expensive and one purpose of the present invention therefore is to provide a cheap and effectively working mass marker. In order to accomplish this and other purposes the invention has been designed according to the claims.

The invention will now be further explained with reference to the accompanying drawings, in which

FIG. 1 shows a mass spectrum,
FIG. 2 constitutes a top view, showing in principle the construction of a mass spectrometer,
FIG. 3 shows an embodiment of the device according to the invention,
FIG. 3A is a fragmentary view on an enlarged scale of the articulated connection between frame members 7 and 8,
FIG. 4 shows another embodiment of the device according to the invention.

Generally mass spectrometry is accomplished in that way (see FIG. 2) that a gas, containing the substances to be analysed, is introduced into the mass spectrometer and ionized in its ionization chamber 1, for instance by means of electron impact. The ions are accelerated and focused by particular electrodes 2 and are then passed through a magnetic field 3, where they are separated according to mass and charge according to the formula

$$r = k_1 \cdot \frac{(U \cdot m/e)^{1/2}}{B}$$

where $k_1$ is a conversion factor, $r$ denotes the radius of the ion path, B the magnetic field strength, $m$ is the mass, $e$ the charge, $m/e$ is the mass number and U the accelerating voltage. The separated ions which hit the detector slit 4 have been deflected with a radius specific for the mass spectrometer. After the ions have passed the detector slit and the magnetic field they are captured in a so called screening-cage or are allowed to hit the first dynode of an electron multiplier 5. The output of the electron multiplier is connected to a recording device, for instance comprising a UV-recorder.

The result can also be recorded in an analogue-digital way. When the sample is ionized a part of the total ion current is indicated by means of an electrode 6 which is connected to an amplifier and a potentiometer recorder. The recording of a mass spectrum is generally started when the ion current is reaching a maximum value. In the analysis the accelerating voltage or the magnetic current i.e. the magnetic field strength could then be continuously varied, thus accomplishing scanning.

A mass spectrum can be relatively complicated with many peaks for each organic substance. A certain mass spectrum is characteristic of a substance and may be utilized for structure determination. The mass spectrum can for instance have the appearance as is obvious from FIG. 1, showing a mass spectrum for cholesterol.

In this case the magnetizing current has been varied continuously.

Such a large range of mass numbers as is shown in FIG. 1 ($m/e = 12-386$) can, in contrast, not be covered by altering the accelerating voltage, as the latter should have to be lowered to about 1/32 maximum voltage at the lowest mass number ($m/e = 12/386$). The ion yield, which is changing approximately proportionally to the accelerating voltage, would in that case decrease too much at the high mass numbers.

In recording of mass spectra it is important that each molecule and fragment ion easily can be identified by its mass number. When, in the mass spectrometer, the radius is given for those ions which should hit the detector slit and the accelerating voltage is known, the mass numbers of the ions in question can be expressed as:

$$m/e = k_2 B^2 / U$$

According to the invention the square of the magnetic field deflecting the ions, or the square of a magnetic field proportional to that one, is determined by measuring the force, generated by the magnetic field in question, suitably by means of a resistance strain gage or by a load cell and by transforming the measurement result into electrical signals, for instance via resistance changes in the gage or cell in question.

FIG. 3 shows the device according to the invention in detail. The magnet frame comprises two members 7 and 8, being articulately connected to each other by an edge 9, attached to the member 8, which edge 9 is working in a notch 10 in the member 7. In a preferred embodiment the radius of the notch 10 is greater than the radius of the edge 9.

The magnet coils are denoted by 11, the air gap between its poles by 12. Onto the frame members 7 and 8 attachments 13 and 14, respectively, are affixed, forming an air gap 15. In the air gap 15 a load cell 16 is inserted.

The ion current is passing in the air gap 12. The magnetic field, generated by the magnet and the purpose of which is the deflection of the ion current, produces a force between the frame members 7 and 8 over the air gap 12. As the attachments 13 and 14 are affixed to the members 7 and 8, respectively, over the air gap 15 there is a force $F$ proportional to the force $F$ over the air gap 12. The force $F$ over the air gap 15 is measured by means of the load cell 16. The load cell 16 is preferably working by means of resistance strain gages which alter their resistance linearly with the load.

By the known relation that the force $F$ over the air gap 12 of the magnet is proportional to the square of the magnetic field strength the following relation can be set up to express the mass numbers of those ions which hit the detector. AR is the resistance change in the load cell and $k_2, k_2k_3k_5$ and $k_10$ denote coefficients.

$$m/e = k_2 \cdot B^2 / U$$

$$F = k_2 \cdot B^2$$

$$F = k_2 \cdot F$$

$$\Delta R = k_9 \cdot F$$

$$k_{10} = k_2 / k_3 \cdot k_3 / k_9$$

In FIG. 4 another embodiment of the present invention is shown, which can be used in those cases when it is unsuitable to perform the measurement direct on the main magnet of the mass spectrometer. In the Fig.
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17 denotes a main magnet of a mass spectrometer, 18 denotes the air gap of the main magnet where the ion current of the mass spectrometer is passing and is being deflected, 19 denotes a measurement magnet, connected in series or in parallel to the main magnet 17, 20 denotes a load cell. The measurement magnet preferably should have the same magnetic properties as the main magnet. The measurement magnet is preferably designed as the device of FIG. 3. The measurement magnet could also be designed in such a way that the load cell 16 is situated in the air gap 12. The invention should not be restricted to the use of a load cell, working by resistance strain gages, for determining the force between the magnet frame members. The mentioned force could be measured by any suitable force measuring means which converts the force to an electrical output signal. The device according to FIGS. 3 and 4 can also be completely or partly immersed in a cooling medium, for instance oil. Temperature compensation can also be achieved by bridge connection.

At rapid dynamic courses, that is at rapid variations of the magnetizing current, an unfavourable lag might appear in the output signal of the load cell. Compensation for this lag may be accomplished in the electronics, connected to the load cell.

It should be appreciated that the embodiment shown above are examples and that the invention should not be restricted thereto.

1 claim.

1. In mass spectrometers of the type wherein a stream of ions is deflected by electromagnetic means and the amount of said deflection may be varied by varying the strength of the magnetic field generated by said electromagnetic means, the improvement which comprises an electromagnet having two pole pieces which together define the air gap through which the deflected ions pass, means to connect said pole pieces together for relative movement in response to changes in the strength of the magnetic field generated, and mechanical force measuring means to resist said relative movement and to generate an output signal linearly proportional to the square of the strength of said magnetic field.

2. The invention according to claim 1, wherein said means to connect said pole pieces includes two members articulately connected together and forming the frame for said pole pieces.

3. The invention according to claim 2, wherein said force measuring means comprises resistance strain gage means.

4. In mass spectrometers of the type wherein a stream of ions is deflected by electromagnetic means and the amount of said deflection may be varied by varying the strength of the magnetic field generated by said electromagnetic means, the improvement which comprises first and second electromagnetic means, each of said means including an air gap, said stream of deflected ions passing through the air gap of said first electromagnetic means, circuit means connecting said first and second electromagnetic means to be energized proportionally from a common source of electrical energy, and resistance strain gage means to measure the strength of the magnetic field in the air gap of the second electromagnetic means as a function of the strength of the magnetic field in the first air gap, said second electromagnetic means including means to support the pole pieces defining the second air gap for movement toward and away from each other, and means connecting said resistance strain gage means to oppose said movement.

5. The invention according to claim 4, wherein said means to support said pole pieces includes two members articulately connected together and forming the frame for said pole pieces.

6. The invention according to claim 5, wherein the strength of the magnetic field generated in each of the respective air gaps of the first and second electromagnetic means is essentially the same.

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